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CONSIDERATIONS CONCERNING THE CARBON MONOXIDE CONCENTRATIONS IN THE VICINITY OF INTERSECTIONS

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CONSIDERATIONS CONCERNING THE CARBON MONOXIDE CONCENTRATIONS IN THE VICINITY OF INTERSECTIONS

[Kōsaten shūhen no issanka tanso nōdo ni tsuite no kōsatsu]

by

Kinji Nakamura and Toshio Ōhira

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1. Introduction

The weight occupied by automobile emission gases in urban atmospheric pollution has been increasing year by year, so that it appears that the seriousness of the situation has now reached its peak.

Countermeasures are also being pushed forward at a rapid pace, chiefly with the regulations of automobile emission gases. In February, 1970 there were established living environmental standards for carbon monoxide (CO), which is the representative pollutant contained in automobile emission gases. Thus, all the necessary formalities have more

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or less been completed.

When evaluating the degree of environmental pollution or the efficacy of countermeasures, the usual practice is to base one's evaluations on the concentration of the pollutants in the atmosphere. However, there are many difficult problems involved in the measurement of environmental concentrations. For example, (1) how many measuring points are needed in Tokyo? (2) How representative are the data from the individual measuring points with respect to the mean concentrations for short periods (8 hours - 24 hours) which are used as the environmental standards for CO? (3) What sort of measuring points are desirable for making broad-area evaluations of the pollution over the entire city area?

This report deals with fundamental studies which were made for the purpose of evaluating carbon monoxide pollution on the basis of the data from an environmental survey concerning automobile emission gases carried out during fiscal year 1969.

2. Survey Methods

(1) Location of the Measuring Points (see Fig. 1)

As a general rule, measuring points for each intersection were set up altogether at 20 points: four points inside the sidewalk (on the side towards the buildings) at the four corners of the intersection; eight points on the inside of the sidewalk along the road at a distance about 100 meters away from the intersection; four points at a distance of 50 meters inside from the road; and four points at a distance of 100 meters inside from the road. Other conditions were taken into consideration to a certain extent in locating the measuring points in

certain special intersections.

In all cases, the measuring points were located at a height of 120 cm to 150 cm above the ground.

Fig. 1. Location of sampling points

(2) Collection of Samples

A small-size diaphragm pump was used, with the flow rate set at about 0.4 ℓ/min by means of the bypass and the orifice. Air was collected for 60 minutes in a Mylar (polyethylene terephthalate, Du Pont) or PVC bag with a contents of 20ℓ - 40ℓ, and this air was used as the samples.

On account of considerations of the analytical capacity, as a general rule samples were collected six times a day: 8:00 - 9:00 hours, 9:00 - 10:00 hours, 12:00 - 13:00 hours, 13:00 - 14:00 hours, 17:00 - 18:00 hours, and 18:00 - 19:00 hours.

(3) Measurements of Amounts of Traffic

The numbers of vehicles entering the intersection were counted with respect to the four directions and the types of vehicle (diesel or gasoline vehicles). The counting time was for 30 minutes and was synchronized with the CO measuring time.

(4) CO Analysis

The samples were connected with a non-dispersive infrared analyzer (URA-2 and APMA-1), and analysis and recording were performed for periods of three to five minutes.

3. Results of Study

(1) Relationships between Four Corners of Intersections (see Tables 4 - 7)

A characteristic feature of environmental pollution by automobile emission gases is the fact that high concentrations occur in extremely localized areas in the close vicinity of the source. Consequently, with reference to a single intersection, on account of the construction of the intersection, the width of the road, the structure of the nearby buildings, the meteorological conditions, and the characteristics of the flow of traffic (prohibition of right turns, frequent left turns, etc.), it would be difficult to suppose that the intersection or the roads in the vicinity would be polluted uniformly. Naturally, the concept of time must also be added when one is making an evaluation, but this would be even more so within the short periods of time such as eight hours or 24 hours which are provided in the environmental standards.

Here testing was performed in order to find out whether one would

be justified in assuming that each set of measured values measured simultaneously at the four corners of an intersection has a statistically uniform mean or not. However, the temporal correspondences were not taken into consideration.

The results of calculations for seven intersections in Tokyo are shown in Tables 1 - 7. In all cases the results obtained indicated that the mean values cannot be regarded as identical.

Table 1. CO concentration at Yanagi-cho intersection (ppm)

1	2	3	4	5	6
Y - A	43	3.0	30.6	11.73	7.72
Y - B	43	7.5	27.2	16.53	4.97
Y - C	42	6.2	23.1	11.44	3.46
Y - D	41	5.7	21.8	13.17	3.60

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8	9	10	11
J	8440.60	3	2813.5
R (J)	4578.63	128	35.77
R J	3861.97	130	

FO = 78.655
F (3,128) : 2.68, 3.94

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

Table 2. CO concentration at Kashiwagi 4-chome intersection (ppm)

1	2	3	4	5	6
K-A	30	2.7	16.2	10.49	3.62
K-B	30	9.2	22.0	13.51	2.72
K C	30	2.4	21.1	8.08	4.68
K-D	30	7.8	34.1	17.54	7.05

7 不偏分散分析表

8	9	10	11
J	1498.81	3	499.6
R (J)	2698.5	117	22.868
R J	4167.31	119	

FO = 21.90
F (3,117) : 2.68, 3.94

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

Table 3. CO concentration at Hibiya intersection (ppm)

1	2	3	4	5	6
H-A	33	2.9	16.4	9.47	3.81
H-B	33	2.6	15.1	7.72	3.22
H-C	34	2.8	21.0	10.27	5.24
H-D	34	3.8	21.0	11.49	4.77

7 不偏分散分析表

8	9	10	11
J	251.48	3	83.827
R (J)	2456.62	131	18.753
R J	2708.1	133	

FO = 4.47
F (3,131) : 2.68, 3.44

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

Table 4. CO concentration at Kumanojinjamae intersection (ppm)

1	2	3	4	5	6
Ku-A	43	4.0	28.1	11.24	6.47
Ku-B	43	0.7	18.1	5.74	4.01
Ku-C	43	2.8	14.0	8.26	2.77
Ku-D	42	7.0	25.8	13.38	4.84

7 不偏分散分析表

8	9	10	11
J	1433.57	3	477.86
R (J)	3726.33	168	22.18
R J	5159.8	170	

FO=21.541
F (3,168) : 2.67, 3.91

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

Table 5. CO concentration at Haginaka intersection (ppm)

1	2	3	4	5	6
Ha-A	24	6.0	19.5	10.42	3.76
Ha-B	24	5.5	20.5	10.67	3.79
Ha-C	24	5.0	14.0	8.91	2.70
Ha-D	24	3.5	13.0	6.90	2.61

7 不偏分散分析表

8	9	10	11
J	427.51	3	142.50
R (J)	983.98	92	10.58
R J	1411.49	95	

FO=13.46

F (3.93) : 2.70, 3.98

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

Table 6. CO concentration at Magome intersection (ppm)

表6 馬込交差点CO濃度(ppm)

1	2	3	4	5	6
M-A	16	4.5	10.5	7.18	1.87
M-B	15	1.0	10.0	4.00	2.32
M-C	16	1.0	8.5	4.46	2.02
M-D	17	4.0	11.5	6.55	1.88

7 不偏分散分析表

8	9	10	11
J	114.82	3	38.27
R (J)	247.33	61	4.05
R J	362.54	63	

FO=9.439

F (3.61) : 2.76, 4.13

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

Table 7. CO concentration at intersection in front of Akamatsu Elementary School (ppm)

表7 赤松小前交差点CO濃度(p p m)

1 採取地点	2 試料数	3 最小	4 最大	5 平均	6 標準偏差
A－A	17	3.0	15.5	8.05	3.80
A－B	18	1.5	9.5	5.86	2.51
A－C	18	1.0	9.5	5.63	2.46
A－D	17	3.0	13.5	7.20	3.14

7 不偏分散分析表

8 要因	9 変動	10 自由度	11 不偏分散
J	68.584	3	22.86
R (J)	17.243	63	0.27
R J	51.307	63	

FO=83.52
F (3.63) :2.75, 4.10

Key:
1. Sampling point
2. Number of samples
3. Minimum
4. Maximum
5. Mean
6. Standard deviation
7. Analysis of unbiased estimate of population variance
8. Factor
9. Variation
10. Degree of freedom
11. Unbiased estimate of population variance

(2) Relationships between CO Concentrations by Blocks

In view of the above-mentioned relationships between the four corners of the intersections, it was decided to use the mean value of the four corners as the value for the intersection. The correlations between these values and the mean value along the road (in most cases, at eight points) and the mean value for the points away from the road were analyzed. As a result, extremely good correlations were found to exist, as will be shown below, and it appears to be possible to make estimates of the pollution in surrounding areas on the basis of the mean value for the four corners of the intersection. The regression coefficient was calculated under the assumption that the point of origin would be traversed.

a. Ushigome Yanagi-cho intersection

The relationship between the CO concentration at the intersection (x) and the mean CO concentration at the points 100 m along the roads (y) is:

$y = 0.567x \quad r = 0.986 \quad n = 32$

The relationship between the mean CO concentration at the intersection (x) and that of the five-way intersection (y) is:

$y = 1.147x \quad r = 0.760 \quad n = 42$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration in the hinterland 50 - 100 m away from the road is:

$y = 0.189x \quad r = 0.854 \quad n = 32$

b. Kashiwagi 4-chome intersection

The relationship between the mean CO concentration at the intersection (x) and the mean concentration at the points 100 m along the road (y) is:

$y = 0.761x$ $r = 0.794$ $n = 30$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration in the hinterland 50 - 100 m away from the road is:

$y = 0.232x$ $r = 0.778$ $n = 30$

c. Hibiya intersection

The relationship between the mean CO concentration at the intersection and the mean CO concentration at the points 50 m along the roads is:

$y = 0.785x$ $r = 0.905$ $n = 32$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 100 m along the roads (y) is:

$y = 0.793x$ $r = 0.802$ $n = 32$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 150 m along the roads is:

$y = 0.769x$ $r = 0.926$ $n = 32$

The relationship between the mean CO concentration at the intersection and the mean CO concentration inside Hibiya Park is:

$y = 0.387x$ $r = 0.733$ $n = 32$

d. Kumanojinjamae intersection

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 100 m along the roads (y)

is:

$y = 0.865x$ $r = 0.940$ $n = 37$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 200 m along the roads (y) is:

$y = 0.756x$ $r = 0.924$ $n = 37$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at points 50 m in from the roads (y) is:

$y = 0.494x$ $r = 0.934$ $n = 37$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at points 100 m in from the roads is:

$y = 0.406x$ $r = 0.926$ $n = 37$

e. Haginaka intersection

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at points 100 m along the roads (y) is:

$y = 0.588x$ $r = 0.907$ $n = 18$

The relationship between the mean concentration at the intersection (x) and the mean CO concentration at points 50 m away from the roads (y) is:

$y = 0.504x$ $r = 0.871$ $n = 18$

The relationship between the mean concentration at the intersection and the mean CO concentration at points 100 m away from the roads is:

$y = 0.459x$ $r = 0.876$ $n = 18$

f. Magome intersection

The relationship between the mean CO concentration at the intersection

(x) and the mean CO concentration at the points 100 m along the roads (y) is:

$y = 0.736x$ $r = 0.873$ $n = 17$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 50 m - 100 m away from the roads (y) is:

$y = 0.461x$ $r = 0.805$ $n = 17$

g. Intersection in front of Akamatsu Elementary School

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 100 m along the roads is:

$y = 0.739x$ $r = 0.953$ $n = 18$

The relationship between the mean CO concentration at the intersection (x) and the mean CO concentration at the points 50 - 100 m away from the roads (y) is:

$y = 0.451x$ $r = 0.842$ $n = 18$

(3) Relationship between Mean CO Concentration at Intersection and Amount of Automobile Traffic

The correlation coefficients at the various intersections were: Ushigome Yanagi-cho intersection 0.880 (n = 16); Kashiwagi 4-chome intersection 0.148 (n = 30); Hibiya intersection 0.824 (n = 34); Kumanojinjamae intersection 0.614 (n = 36); Haginaka intersection 0.120 (n = 23); Magome intersection 0.246 (n = 17); and Akamatsu intersection 0.341 (n = 18). In most cases there was not a significant correlation.

4. Discussion

(1) Measurements at the Intersections

As is clear from the results of analysis of variance, measurements at one place are insufficient to find the CO concentration in the four corners of an intersection. The results indicate that the mean concentration values at the largest possible number of measuring points must be considered as the representative values for the intersection. Some studies were made separately concerning this point. It was assumed that the mean values (hourly) for the four corners of the intersection were the values representing the intersection. The Ushigome Yanagi-cho intersection was taken as a model, and the deviations were calculated for cases when there were one, two, and three measuring points. The results showed that, when there was one measuring point, the deviations from the representative values were 1.86 ppm - 5.02 ppm. When there were two measuring points, the deviations were 1.98 ppm - 2.47 ppm, and when there were three measuring points they were 0.61 ppm - 1.68 ppm. (Refer to Table 8.) The correlations between the mean CO concentration for the intersection and the CO concentration at the points in each of the four corners were sought for four different intersections, and the results are shown in Table 9. There were few cases which had both a good correlation coefficient and a good regression coefficient, and it was noteworthy that there were some corners where almost no relationship at all could be found. The fact that satisfactory results could not be obtained with measurements of one corner of an intersection indicated that the air within the

intersection is not uniformly polluted. Possible reasons for this are the effects of the meteorological conditions, the characteristics of the flow of traffic, and the structure of the intersection.

Table 8. Number of Measuring Points and Deviations at Ushigome Yanagi-cho Intersection

1	2	3	4
A	42	1043.130	4.967
B	42	1057.400	5.017
C	42	411.610	3.191
D	42	115.920	1.863
A・B	42	164.270	1.977
B・C	42	250.050	2.559
C・D	42	164.250	1.977
A・C	42	247.580	2.427
A・D	42	238.790	2.384
B・D	42	255.450	2.466
A・B・C	42	15.660	0.609
A・B・D	42	44.800	1.032
B・C・D	42	118.030	1.676
A・C・D	42	116.960	1.668

Key:
1. Measuring points
2. Number of data
3. Sum of squares of deviations
4. Mean deviation

Table 9. Relationship between Four Corners of Intersection and the Mean Value

1		2	3	4	5
A	r	0.854	0.399*	0.900	0.920
	a	0.978	0.629	0.969	1.237
	n	43	30	33	43
B	r	0.652	0.633	0.832	0.849
	a	0.954	1.061	0.790	0.640
	n	43	30	34	43
C	r	0.772	0.625	0.626	0.056**
	a	1.221	0.672	1.061	0.769
	n	42	30	34	42
D	r	0.878	0.880	0.773	0.766
	a	0.845	1.455	1.176	1.359
	n	43	30	33	43

Key:
1. Measuring points
2. Ushigome Yanagi-cho
3. Kashiwagi 4-chome
4. Hibiya
5. Kumanojinjamae

(Notes): r: Correlation coefficient a: Regression coefficient

n: Number of samples

* No significant correlation with a 2% level of significance

** No significant correlation with a 10% level of significance

(2) Comparison of the CO Concentrations for Different Blocks

As is shown by the results of the calculations, there is a good relationship between the mean concentration at the intersection and the mean concentration of each block, and it would seem possible to estimate the concentration in the surrounding areas, using the mean value at the intersection as the intersection concentration.

Since the CO concentration at places more than 50 m away from the road drops to less than half of the concentration at the intersection, when the degree of pollution is to be determined according to the environmental standards, it will be particularly important to take into consideration the exact definition of the area in question.

(3) Amount of Automobile Traffic and Mean CO Concentration at the Intersection

At the Haginaka, Magome, and Akamatsu intersections, the correlation was not significance with a 10% level of significance, and at the Kashiwagi 4-chome intersection there was an inverse correlation (not significant). It is believed that these unexpected results were obtained for the following reason. That is, since the measurements were taken only during the daytime, there was a narrow range of fluctuation of the amount of automobile traffic. Furthermore, the influence of the meteorological conditions on the CO concentration was great.

For example, at the Kashiwagi 4-chome intersection, during the survey period there were poor meteorological conditions, with the appearance of smog, on Sunday, when there was little traffic, and the correlation deteriorated for this reason. It was confirmed that the correlation coefficient improved somewhat when Sunday was excluded from

the calculations.

5. Summary

Analyses were made for seven intersections, chiefly concerning the CO concentration, without taking the meteorological conditions into consideration. The findings were the following.

(1) Measurements at intersections ought not to be taken at a single place (one corner). Rather, the mean value of the largest possible number of points ought to be used as the representative.

(2) Since the mean CO value at the four corners of an intersection has a good correlation with the values in the vicinity of the roads and in the hinterland, it ought to be possible, after measuring the values at an intersection, to estimate the concentrations in the nearby areas.

(3) The relationship between the amount of traffic and the CO concentration could not be grasped fully when the measurements were taken during the daytime only.

(4) Since CO pollution is localized, it is especially necessary to give careful consideration to an exact definition of the area in question when one is making determinations in accordance with the environmental standards.